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De Paul Univ, Chicago, IL

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Project Officer: Michael D. Mullin,ERL - Duluth, Grosse Ile, MI 48138

16. ABSTRACT

Rainfall samples were collected in Chicago, Illinois, and on Beaver Island, Michigan, and analyzed for polychlorinated biphenyls (PCBs). The precipitation weighted mean concentration of 35 samples of rain was 111 ng/l. (111 parts per trillion). This would result in the deposition of 4800 kg/yr of PCBs to the Lake from precipitation. Presently available evidence on other sources of PCBs to the Lake indicates that precipitation is now the major source of PCBs to the Lake. The future PCB problems in the Lakes will then be determined mainly by the magnitude of atmospheric inputs to the Lake.

The concentrations of PCBs in rainfall were found to be as high on Beaver Island as in Chicago.

Results obtained from the simultaneous sampling of air and precipitation indicate that PCBs are present in the atmosphere as vapor as well as being present on particulates. This result raises doubts as to the validity of results for the dry deposition of PCBs obtained from the use of collectors covered with mineral oil or other non-polar liquid.

PCB concentrations in the parts per billion range obtained from gas samples from a vented sanitary landfill, indicate that PCB containing materials incorporated into landfills may be an important source of PCBs to the atmosphere.

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by

Thomas J. Murphy
Charles P. Rzeszutko
DePaul University
Chicago, Illinois 60614

Grant No. 803915

Project Officer

Michael D. Mullin
Large Lakes Research Station
Environmental Research Laboratory - Duluth
Grosse Ile, Michigan 48138

ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
DULUTH, MINNESOTA 55804

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FOREWORD

The presence of hazardous materials in the environment is a topic of major interest to the Environmental Protection Agency. Elevated levels of polychlorinated biphenyls (PCBs) in some species of Great Lakes fish have necessitated the recommendation that persons limit, or eliminate, their dietary intake of these fish. In order to develop an understanding of the pathways by which PCBs move within a lake ecosystem, it is necessary to determine first the routes and amounts of these pollutants entering the lake.

This report addresses the input of PCBs from the atmosphere to Lake Michigan. The differentiation between gaseous and particulate forms are measured as well as the comparison between urban and rural input rates.

Michael D. Mullin, Ph.D.
Project Officer
Large Lakes Research Station
Environmental Protection Agency-Duluth
Grosse Ile, Michigan

ABSTRACT

Event rainfall samples were collected in Chicago, Illinois and on Beaver Island, Michigan and analyzed for polychlorinated biphenyls (PCBs). The volume weighted mean concentration of 35 samples of rain was 111 ng/L (111 parts in 10^{12}) of PCBs as Aroclor® 1242 + 1254 + 1260. This would result in the deposition of 4800 kg/yr of PCBs to Lake Michigan from precipitation.

The concentrations of PCBs in rainfall were found to be as high on Beaver Island as in Chicago. This, and the finding of PCBs in the air and precipitation in remote areas, is interpreted as indicating that the sources of PCBs to the atmosphere are diffuse and that residence times in the atmosphere are long.

A comparison of the results obtained from air and precipitation sampling, including simultaneous sampling, indicates that the majority of PCBs are present in the atmosphere as vapor with the remainder being present on particulates. This result, along with the high solubility of PCBs in non-polar organics, raises doubts as to the validity of measurements for the dry deposition of PCBs obtained with the use of collectors covered with mineral oil or other non-polar liquids.

Two gas samples obtained from a vented sanitary landfill had PCB concentrations in the $\mu g/m^3$ (parts in 10^9) range. This indicates that PCB containing materials incorporated into landfills may be an important source of PCBs to the atmosphere.

With the decline in the use and discharge of PCBs by major industrial facilities in the basin, PCB levels in Lake biota may decline by a factor of four or more. Precipitation is now the major known source of these materials to the Lake, and the future problems in the Lake with PCBs will be determined mainly by the magnitude of the atmospheric inputs of PCBs to the Lake.

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SECTION 1

INTRODUCTION

In recent years, fish species in Lake Michigan, especially the salmonids, have contained high levels of DDT and its degradation products, and polychlorinated biphenyls (PCBs). In most cases, the large fish are above the Food and Drug Administration (FDA) limit for these materials of 5 mg/L (Willford 1975). Among the Great Lakes, the levels of DDT and its degradation products in the late 1960's and then of PCBs in the 1970's, have been the highest in Lake Michigan (IJC 1974; 1976).

PCBs are a serious health hazard to many species of animals and to man. It has been shown that the cause of the reproductive failures in ranch mink fed Lake Michigan fish during the middle 1960's, was due to PCBs in the fish (Aulerich et al. 1973). Fish are now practically the sole source of PCBs in the human diet (Jelinek and Corneliussen 1976). Breast fed infants throughout the country (Savage et al. 1973; Musial et al. 1974; Grant et al. 1976) are now exposed to 10% of the dosage of PCBs which has been shown to cause serious health problems in rhesus monkeys (Allen and Norback 1976; Barsotti et al. 1976). A correlation between the number of Lake Michigan fish consumed and the blood levels of PCBs in humans has been reported (Humphreys 1976). The public press has reported the case of one fisherman who developed the symptoms of PCB poisoning, Yusho disease, after having eaten large quantities of Lake Michigan fish (Ingersoll 1977).

The cause of the DDT problem was probably the use of this insecticide in the agricultural regions around the Lake, and for Dutch Elm disease control in the urban areas at the south end of the Lake. It is believed that an important route for the dissemination of DDT and its metabolites is atmospheric transport as vapor, mist and material adsorbed on particulate matter (Woodwell et al. 1971; 1972). This material could then enter the Lake by both wet and dry deposition.

When the use of DDT was halted in Wisconsin and Michigan, and then nationwide in the late 1960's, the levels of DDT and its metabolites in the fish dropped rapidly over the next several years. For instance, the level in bloaters (chubs, Coregonus hoyi) dropped 87 percent from 1970 to 1975, and the level in Lake Trout (Salvelinus namaycush) dropped 53 percent during the same time period. This indicates a relatively short residence time in the Lake for these materials.

The problem with PCBs became apparent during the time of the problems with DDT. Since many of the chemical and physical properties of the PCBs

are similar to those of DDT, there was a lot of accumulated experience with this type of problem to draw on. Thus it was expected that the voluntary ban on "open" uses of PCBs in 1971 by the sole U. S. manufacturer, would lead to a decline in PCB levels in the fish similar to that which had occurred with DDT (Buckley 1972). Unfortunately, this did not happen. PCB levels in bloaters in 1974 were unchanged from those in 1972 and the levels in lake trout rose about 50% during the same time period (Willford 1975).

In 1975 then, it was not known why the PCB levels in the fish in Lake Michigan were continuing to increase. Several possible explanations for this increase are:

1. The chemistry of the PCBs in the Lake is different from that of DDT.

2. The slower degradation of many of the PCB isomers increases the residence time of the PCBs in the Lake.

3. One of the "closed" use of PCBs was the major source of the PCBs getting into the Lake.

4. The large reservoir of PCBs manufactured before 1971, and already used or still in use, continue to enter the environment.

Since the measurement of PCBs in tributaries and waste water treatment plants had shown that only a small amount of PCBs were entering the Lake by those routes, since the atmosphere had been a major source of DDT to the Lake, and since PCBs had been identified in precipitation in other areas (Tarrant and Tatton 1968; Sodergren 1972; 1973), it was thought that the atmosphere could also be transporting PCBs to the Lake. This assumes that the fourth explanation above is the cause of the PCB problem in the Lake.

This study was initiated to determine the amount of PCBs which were being transported to the Lake by the precipitation scavenging of PCB-containing particulate matter from the atmosphere, and to make some measurements on the concentration of PCBs to the atmosphere. Information on the distribution of PCBs between the soluble and particulate fraction in precipiation was obtained and the compostion of the PCBs with respect to the different isomers present in the samples was determined. Also, the PCB concentration and composition in gases vented from a sanitary landfill were measured.

While this project was not directed to the determination of sources of PCBs to the atmosphere, a convenient opportunity to measure such a source exists in the Chicago area and such measurements were made.

A potential source of PCBs to the atmosphere is material incorporated into sanitary landfills. If PCBs in paints, plastics or carbon-less paper, or in containers such as PCB filled capacitors which have broken open, are

present in a landfill, they can evaporate. Since gases are generated by the anerobic decomposition of organics within landfills, and continually escape to the atmosphere, PCBs which evaporate in the landfill would be carried out along with these gases.

An above ground landfill has been constructed in a suburb of Chicago and is used for recreational purposes. The landfill has been carefully sealed with clay, and several gas wells have been put in place to vent gases generated within the landfill to the atmosphere. These gases have been sampled by the Illinois Geological Survey and, on a volume basis, consist mostly of methane (69%), and carbon dioxide (29%).

SECTION 2

SAMPLING

To meet the objectives of this project, air and event precipitation samples were collected in Chicago, Illinois at DePaul University (41° 55.4'N; 87° 39.9'W) from July 1975 through January 1977, and rain samples were collected on Beaver Island (45° 40'N; 85° 31'W), 500 km from Chicago, from May through October 1976. The sampler in Chicago was located about 15 meters above the ground on the roof of a building, 2 km west of Lake Michigan, 4 km north of the central business district of Chicago in a densely populated urban area which also contained some light manufacturing. The sampler on Beaver Island (Figure 1), 500 km north of Chicago, was one meter above the ground and about 30 meters from the shore on the east side of the Island on the grounds of the Biological Station of Central Michigan University.

Air samples were collected in Chicago at the above location, and within the boundaries of Mammoth Cave National Park (37° 13'N; 86° 03'W). In addition, several water samples from Lake Michigan were collected and some samples obtained of gases vented from a sanitary landfill.

When possible, samples were filtered upon collection, and thus separate samples of PCBs associated with the non-filterable as well as the filterable portions were obtained. The samples were cleaned-up and analyzed for the PCBs present. Since the commercial PCB products, the Aroclors®, contain mixtures of different PCB compounds, the weight of the individual PCB compounds found in the samples was determined, summed, and reported as the Aroclor® in which they predominately occurred. The Aroclor® mixtures reported here are 1242, 1254 and 1260. In no case did the relative amounts of the different PCB® compounds found in the samples approximate the ratios found in the Aroclors®.

Polychlorinated biphenyls (PCBs) are liquids or solids at room temperature. They are non-polar, slightly soluble in water (56 µg/L for Aroclor® 1254 at 25°C; Haque et al. 1974) and they have a slight vapor pressure (7.7×10^{-5} mm for Aroclor® 1254 at 25°C; Mackay and Wolkoff 1973). Thus PCBs in the environment can be expected to be present in the air, water and solid phases, which greatly complicates the sampling for them.

In addition, the concentration of PCBs in most environmental samples was expected to be less than 1 ng/g (1 part in 10^9). Thus the collection and handling of large samples is necessary to get sufficient PCBs for

FIGURE 1. MAP OF SAMPLING LOCATIONS.

analysis. Also, in order to collect remote samples, a means of concentrating or processing the sample at the collection site, with a minimum of effort on the part of the sampling personnel, was necessary.

The polyurethane foam collection method for PCBs of Uthe et al. (1973) was chosen. This method involves passing a liquid or gas stream over pieces of polyurethane foam coated with a non-polar liquid. The PCBs are soluble in the liquid and the foam, and are very efficiently scrubbed from the water or gas stream by the foam. They are then extracted from the foam in a Soxhlet extractor.

Precipitation was collected on a galvanized steel surface and the water ran-off to the sampler described below. The surface of the collector was cleaned before each precipitation event to minimize the amount of dry fallout incorporated into the sample. The design of the sampler used for the rain collections on Beaver Island is shown in Figure 2. The collector used at DePaul worked the same but was slightly different in construction. The sampler works as follows. When rain is anticipated, the collector is cleaned and the peristaltic pump is turned on. The pump creates a partial vacuum in the apparatus. The water from the collector is channeled to the funnel and drawn through a tared glass fiber filter (GF/A; Gelman Instruments; Ann Arbor, MI) by the vacuum in the apparatus. This separates the particulates in the rain from the "soluble" portion, i.e., the filtrate. The filtrate then flows under gravity through the polyurethane foam, coated with DC-200 silicone oil, in the bottom of the sampler. The water level in the sampler is maintained above the foam by the use of the siphon tube on the discharge. The water is pumped from the sampler into a barrel. After a precipitation event, the volume of water in the barrel is measured to determine the amount of water sampled. The amount of rainfall in an event was separately measured with an adjacent rain gage.

Besides making the determination of the PCBs on particulates possible, the filtration of the rain is necessary since it has been reported that PCBs on particulate matter pass uncollected through polyurethane foam (Bedford 1974).

The partial vacuum in the sampler created an additional problem. Since the water being filtered is saturated with air, it is rapidly degassed after passing through the filter. A bypass was provided for this air to prevent it from interfering with the foam extraction. Some of the PCBs in the water could vaporize at this time. To collect these PCBs, and also any that evaporate from the particulates when air passes through the filter, polyurethane foam was placed in the by-pass.

Finally, to ease the remote operation of the sampler, the portions of the sampler containing the foam are made detachable. Thus, the person handling the sampler at Beaver Island was supplied a number of filters and several sets of the interchangeable parts of the sampler, containing clean foam. After a rain event, the detachable portions of the sampler containing the foam were wrapped in aluminum foil and mailed to DePaul University for extraction and analysis. A new filter and containers with clean foam were

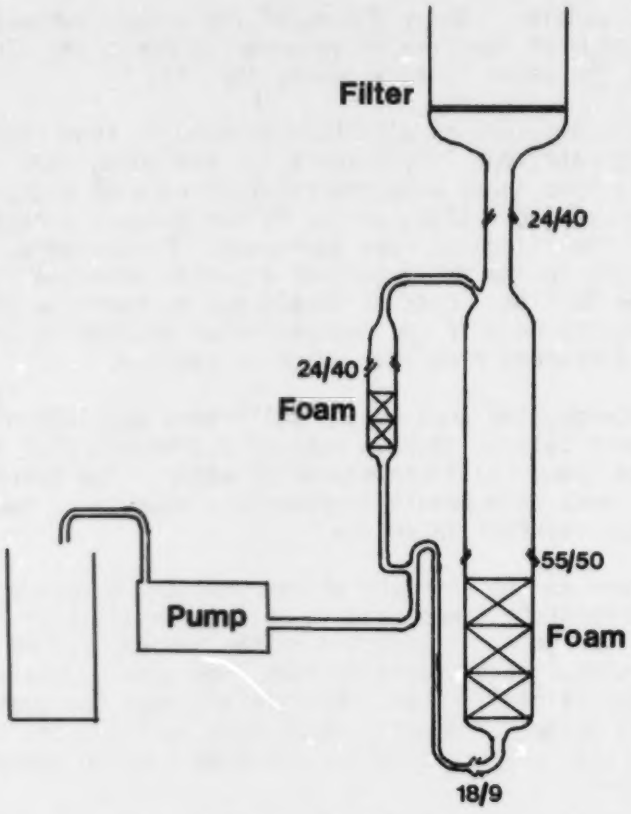

FIGURE 2. PCB SAMPLER FOR WATER SAMPLES.

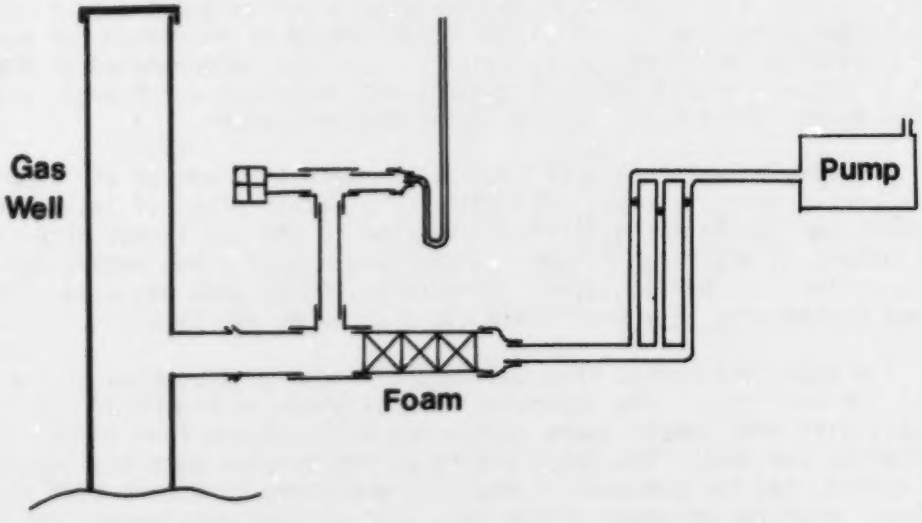

FIGURE 3. SAMPLER SET-UP FOR SAMPLING GASES FROM A LANDFILL.

placed on the sampler. About 200 mL of 70% ethanol were added to cover the foam in he bottom of the sampler in order to force the air out of the foam and to permit the water to flow freely thru it.

A final complication with this sampler is that the flow rate is fixed by the pumping rate, one liter/minute for the pumps used in this project. Thus, during a rain storm when the rainfall rate is high, not all of the water will be sampled. Also, as the filter becomes clogged with particulates, the filtering rate decreases. Fortunately, much of the particulates are in the early part of the rain when the filtering efficiency of the sampler is high. Loss of sample due to overflow of the filter will affect the results only if the concentration of PCBs in the portion which overflows is different from that which is sampled.

The interception area of the collectors was 1.29 m^2 at DePaul and 1.2 m^2 at Beaver Island. A rain rate of 0.8 mm/min (1.9 in/hr) then corresponds to about one liter/minute of water. The average rainfall intensity for most rain events is much less than this, but many contain periods of high rainfall intensity.

To determine the severity of the problem, a recording rain gage (Belfort Instrument Co.) was used in Chicago in addition to the standard accumulation type gage. Inspection of the records for 20 rain events showed that while a significant amount of rain from some events occurred during periods of high rainfall rates, the rainfall rate for most of the water which fell was below 0.8 mm/min. With some variability, the average volume of sample per unit of precipitation was 1.06 L/mm in Chicago and 0.98 L/mm on Beaver Island.

This problem could be minimized further or corrected for in several ways: the area of the collector could be decreased; the area of the funnel could be increased to lower its flow resistance and spread the particulates over a larger area; the volume of the funnel could be increased for more storage capacity; and finally, an overflow could be incorporated on the funnel to collect excess water in an adjacent container which would then be manually poured through the sampler after the rain event.

Air samples were collected with a standard high volume air sampler (General Metal Works; Cleves, OH) modified to permit plugs of polyurethane foam (Bidleman and Olney 1974) to be inserted in the air stream after the filter paper. Glass fiber filters (GF/A; Gelman Inst.; Ann Arbor, MI) were used to collect the particulates. Five to 7.5 cm of foam was used. The foam was coated with DC-200 silicone fluid (Uthe et al. 1972).

The gases discharged from the landfill vent were sampled at the exit port of the vent pipe. The apparatus used is shown on Figure 3. It permitted different sample tubes containing polyurethane foam to be connected to the vent. The extra piping on the sampler permitted excess gas to be vented, and the pressure in the vent monitored to insure that there was always positive pressure in the vent pipe so that outside air was not drawn into the sampler.

The flow rate of the gases which passed through the sampler was measured by passing this gas through three rotometers connected in parallel. The rotometers had been calibrated by connecting the intact sampling train to a closed 216 L (55 gal) drum which had a manometer connected to it. The sampler was operated for short periods, and volume of air pumped from the drum was calculated from the known volume of the drum and the pressure change caused by the pumping. This permitted the flow rate to be determined. The system was calibrated at several different flow rates.

SECTION 3

ANALYSIS

Solvents used were pesticide grade (Burdick and Jackson Laboratories; Muskegon, MI) or were distilled from glass through a packed column. Drying agents, cotton, and chromatographic packing materials were extracted with hexane/acetone and dried before use. Activated Florisil® was dried at 130°C before use and stored in a closed bottle at room temperature . Aroclor® analytical reference standards (U. S. EPA, Health Effects Research Laboratory, Research Triangle Park, NC) and individual PCB isomers (Analabs Inc.; North Haven, CN) were used as received. Polyurethane foam (density = 0.024 or 0.036 gm/cm^3) was extracted with water, acetone, and acetone/hexane before use.

The polyurethane foam plugs from the samplers were extracted with hexane/acetone in a Soxhlet extractor. The foam from the air bypass was extracted along with the foam from the filtered ("soluble") water fraction. The glass fiber filter containing the particulates, the non-filterable fraction, was separately extracted in a Soxhlet by placing it in a clean, tared cellulose extraction thimble. The extracts from the particulates were evaporated to dryness and their weight determined. This weight is reported as the organic portion of the particulate fraction. The extracts from the foam contained the silicone coating and thus the weight of the organic fraction from the filtered portion could not be obtained.

The extracts from the filtered and non-filterable fractions in hexane, were placed on a hexane-washed Florisil® column. The hexane fraction was collected and concentrated in a Kuderna-Danish evaporator with a three-ball Snyder column.

The weight of the non-extractable particulates was determined by weighing the extraction thimbles containing the filter paper after extraction and subtracting the weight of the thimble and filter. Since the extraction thimbles were hygroscopic, the following procedure was followed to determine their weight. The thimbles, with or without contents, are heated to 110°C for 30-45 minutes in an oven, wrapped quickly in a piece of aluminum foil, and allowed to cool. The foil-wrapped thimble is weighed, emptied of its contents, reheated, and reweighed. The weight of the particulates is obtained by subtracting the weight of the filter and thimble from the total weight. The tare weight of the thimbles was reproducable to ±2 milligrams.

The PCBs in the samples were quantified by the method of Webb and McCall (1973). This involves the use of Aroclor^{R} standards and the percent contribution to these standards of eight or more of their major components to determine the absolute GC detector response factors (area/ng) for each of the 23 major peaks which are separated by the GC. These response factors are then used to determine the amount (ng) of each of the 23 different peaks. Rather than reporting the amount of each of these 23 peaks, they were grouped in a manner very similar to the scheme proposed by Webb and McCall (1973). The peaks which comprised the di-, tri- and most of the tetrachlorobiphenys, were summed and are reported as Aroclor^{R} 1242. The peaks which comprised the remainder of the tetrachlorobiphenyls, along the penta-, and most of the hexachlorobiphenyls were summed and reported as Aroclor^{R} 1254. The peaks which comprised the remainder of the hexachlorobiphenyls, along with the hepta-, and octachlorobiphenyls were summed and reported as Aroclor^{R} 1260. Although the PCBs found in the samples are reported as Aroclors^{R}, in no case did the pattern of PCB peaks in a sample closely resemble that which occurs in a commercial Aroclor^{R} sample.

The PCBs were separated on a 1.8 m x 2 mm, 3% OV-101 GC column temperature programmed from 180 to 220°C. The injector was kept at 260°C and the detector at 350°C. A Ni-63 electron capture detector was used with a pulsed voltage, constant current source. The areas of the different peaks were obtained with the use of a digital electronic integrator (Supergrator-1; Columbia Scientific Ind. Corp.; Austin, TX).

The efficiency of the extraction and clean-up of the PCB samples was checked on several occasions. The efficiency of the recovery of PCBs from the foam and their clean-up was checked twice by adding 2,3,4,5,6-pentachlorobiphenyl (740 & 880 ng) to the foam and extracting with a mixture of hexane/acetone in a Soxhlet for seven hours. The extracts were cleaned-up and analyzed in the normal manner. The overall recovery was 78 and 84 percent. Further extraction of the foam yielded less than one percent additional material.

The efficiency of the clean-up procedure was independently checked on four occasions by adding known amounts of PCB isomers (296 to 840 ng) to the chromatographic clean-up column and proceeding in the normal manner. Recoveries of the added PCBs averaged 95 $\pm$ 11 percent.

On two occasions the three foam plugs from the water sampler were separately extracted. The bottom foam contained no detectable PCBs on both occasions.

One one occasion, the two pieces of foam from the air sampler were separately extracted and analyzed. One fourth of the total PCBs were found on the second piece of foam indicating an overall sampling efficiency of about 88%.

In order to be consistent with the reporting procedures followed by other workers, and to permit easy comparison with other reports, the results here are uncorrected for analytical efficiency.

CALCULATIONS

The object of this project is to determine the inputs of PCBs into Lake Michigan. This is not directly accomplished by determining the concentration of PCBs in precipitation because the concentration of PCBs in a precipitation sample is usually inversely proportional to the amount of precipitation (Hicks 1966; Gatz and Dingle 1971).

To take into account the concentration of PCBs as well as the amount of precipitation, the volume weighted mean concentration of PCBs was determined for the samples. This mean is calculated by multiplying the concentration of PCBs found in the sample (ng/L) by the amount of precipitation (mm) to give an input of PCBs in ng/m^2. The volume weighted mean for the samples in then calculated by summing the inputs for the samples and dividing by the total amount of precipiation the samples represent.

$$\text{Volume weighted mean PCB concentration} = \frac{\sum \text{Concentration X Precipitation}}{\sum \text{Precipitation}}$$

SECTION 4

RESULTS

The volume weighted mean concentration for all of the samples from Chicago and Beaver Island which gave useful results are shown in Table 1.

Four of the samples from Chicago collected early in the project, were not filtered and, based on the results of Bedford (1974), it was presumed that the particulate matter in these samples and their proportion of the PCBs, were inefficiently collected. The concentrations of PCBs found for these samples was then assumed to come only from the filtered portion. From the other 18 samples, it was determined that 34 ± 23 percent of the PCBs were on the particulates. These four samples were included in the results shown above by increasing their PCB concentration by 51 percent (1/(1-0.34)) to approximate the inclusion of the particulates.

A number of different types of samples were collected and analyzed for PCBs during the course of this project. Besides the rain samples, these include: snow samples, Lake Michigan water samples, air samples and gas samples collected at the sanitary landfill. The results obtained from the analyses of these samples are shown in Table 2 along with the percent of the PCBs which was associated with the filtered, ("soluble") part of the sample.

The composition of the samples with respect to the different PCB compounds varied considerably from sample to sample. In general, however, there were different patterns from the different types of samples as shown in Figure 4 and in Table 3. The compositions shown were calculated from the sum of the different Aroclors[R] for all of the samples of each type. For

TABLE 1. VOLUME WEIGHTED MEAN CONCENTRATION OF PCBs IN RAINFALL

	Chicago	Beaver Island
Total amount of precipitation (mm)	386.5	110.1
Number of samples	22	13
Volume weighted mean concentration (ng/L)	104	138

TABLE 2. THE MEAN CONCENTRATION OF PCBs

Sample Type	Number of Samples	Arithmetic Mean PCB Concentration	Percent PCBs in Filtered Portion
Rain (ng/L) Chicago	22	160	66
Beaver Island	13	215	53
Snow (ng/L) Chicago	4	212	36
Lake Water (ng/L) Chicago	2	41	30
Beaver Island	1	30	43
Air (ng/m^3) Chicago	4	7.6	97
Mammoth Cave NP	1	6.7	95
Landfill Gases (ng/m^3)	2	3240	-

the rain samples, a volume weighted mean distribution of the PCBs was also calculated. The results showed little difference from the arithmetic mean. To be consistent, the arithmetic mean of the rain samples is included in Table 3.

For a number of the rain samples, the amount of the hexane/acetone extractable material, the organic fraction, of the particulate portion of the sample was derermined. If it is presumed (see Discussion) that all of the PCBs in the rain samples came from particulates scavenged by the precipitation, then the concentration of PCBs on the particulates and in the organic fraction of the particulates can be determined.

Shown in Table 4 are the results of calculations which show the concentration of PCBs in the total particulates and organic particulate fractions if it is assumed that 1) either all of the PCBs present in the sample were associated with the particulate organics; or 2) that only the particulate PCBs were associated with the particulate organics. For instance, the mean amount of PCBs found on particulates in the rain samples in Chicago was 697 nanograms/sample. If these PCBs are assumed to be associated only with the organics in the particulate matter (8 milligrams/sample), the PCB concentration in the organics is 88 mg/kg. Also, the PCB concentration in the total particulates (260 milligrams/sample) then is 2.6 mg/kg.

Since the organic fraction is small, the errors in their determination are large. Therefore, the weights of this fraction and the calculations based on them are not very precise and should be treated only as approximations.

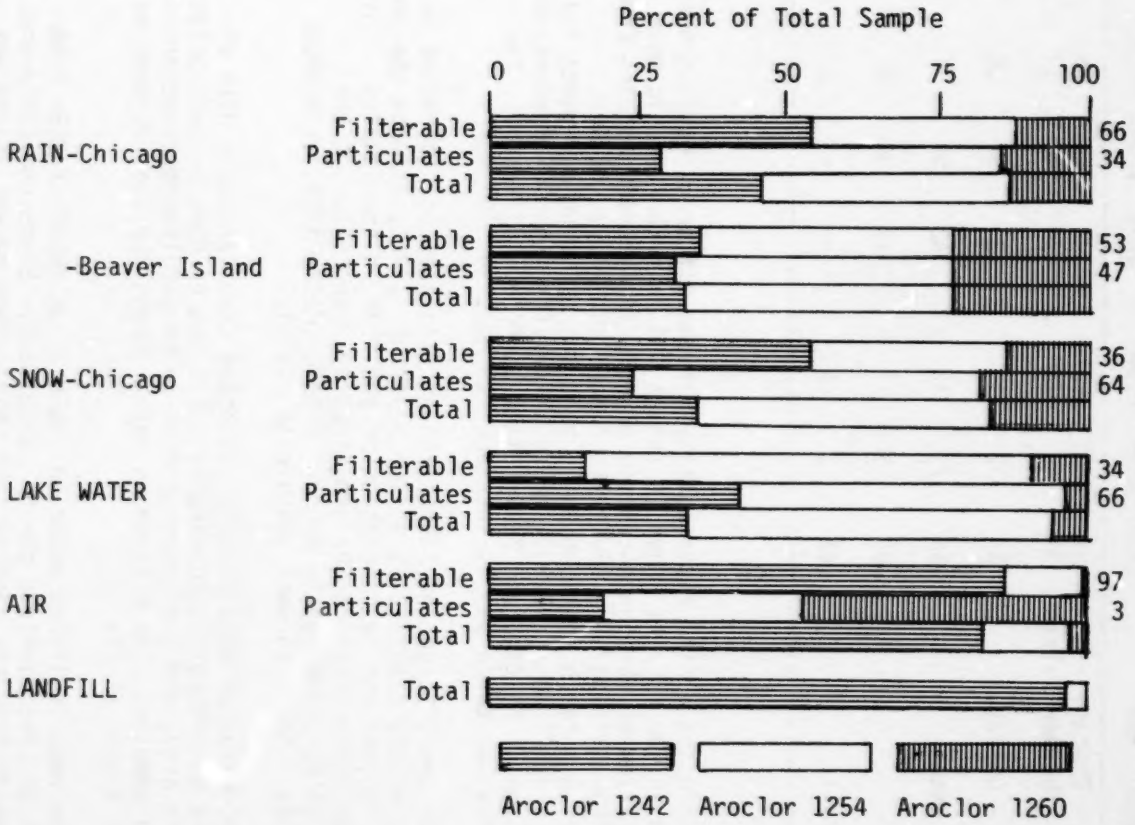

FIGURE 4. THE PCB COMPOSITION OF THE DIFFERENT TYPES OF SAMPLES

TABLE 3. THE AROCLOR^R COMPOSITION OF THE DIFFERENT SAMPLE TYPES

Sample Type	Filtered Aroclors 1242	1254	1260	Non-Filterable Aroclors 1242	1254	1260
Rain - Chicago	54	33	13	29	56	15
Beaver Island	34	43	23	31	46	23
Snow - Chicago	54	31	15	24	57	18
Lake Water	16	73	10	42	54	4
Air	85	14	1	19	34	47
Landfill	98	2	0	-	-	-

There is quite a bit of variability between different samples which is not reflected in the results shown in Tables 1-4. The arithmetic mean and standard deviation of the concentration of PCBs in the rain samples from Chicago and Beaver Island are 160 ± 125.4 ng/L and 215 ± 161 ng/L respectively. A t-ratio test indicates that the difference between these means is not significant (t=1.128; N=35). Therefore the PCB concentration in precipitation in Chicago and Beaver Island are not different. The geometric means for these sample sets are 109 mg/L and 164 mg/L.

For both the Chicago and Beaver Island rain samples, there was an inverse correlation, significant at the 5 percent level, between the amount of precipitation and the concentration of the PCBs in the samples. This is not an unusual finding and can be explained by a depletion of the particulates being scavenged by either rainout (Hicks 1966) or washout (Huff and Stout 1964). See also Gatz and Dingle (1971).

Two precipitation samples were collected simultaneously with air samples. This permitted the scavenging ratio (ng/kg PCBs in precipitation)/(ng/kg PCBs in air), and the types of PCBs to be simultaneouly determined in each of these samples. The scavenging ratios found for the two samples were 13 and 37 for a mean of 25.

From the results listed above in Table 1, an input of PCBs from precipitation to Lake Michigan can be calculated. Since the difference between the means from the samples from Chicago and Beaver Island was not statistically significant, the samples from both locations were combined and a volume weighted mean concentration of 111 ng/L was calculated for all of the samples. This concentration, when multiplied by the mean precipitation on the Lake, 740 mm/yr (Jones and Meredith 1973), the area of the Lake (58,000 km^2), and the units corrected, results in an input of 4800 kg/yr of PCBs to Lake Michigan from precipitation.

TABLE 4. THE CONCENTRATION OF PCBs IN ORGANIC MATTER

	Sample Type				
	Rain		Snow	Lake Water	Air
	Chicago	Beaver Is.			
Number of Samples	17	11	2	3	4
Particulates per Sample (mg)					
Organics	8 ± 8.4	5 ± 5.3	9.8	3.8	10 ± 4
Total	260 ± 195	76 ± 56	140	82	58
PCB Concentration in Particulates					
Total PCBs per Sample (mg/kg)					
Organic Particulates	340	240	220	140	600*
Total Particulates	8	16	11	5.5	200*
Non-Filterable PCBs per Sample (mg/kg)					
Organic Particulates	88	120	150	100	18*
Total Particulates	2.5	7.5	5.5	4	3*

*Biased by the fact that most of the PCBs on air particulates are collected as vapor.

SECTION 5

DISCUSSION

ATMOSPHERIC INPUTS

Extent of the Problem

An unexpected result, and a significant finding, of this study was the finding that the concentration of PCBs in precipitation was as high on Beaver Island as in Chicago. This means that either there is a local source of PCBs to the atmosphere in the vicinity of Beaver Island, which is unlikely, or that PCBs are being very widely distributed by the atmosphere.

There is other evidence to support the wide distribution of PCBs by the atmosphere. Concentrations of 230 ng/L of PCBs have been found in snow samples collected on Isle Royale National Park in Lake Superior (Swain 1977), 800 km north of Chicago. Also, the air sample collected in this project in Mammoth Cave National Park, which is located in a rural area remote from centers of population and industry, and 650 km south of Chicago, had concentrations of PCBs similar to those found in Chicago (Table 2). Strachan et al. (1977) report lower concentrations of PCBs found in precipitation in the Lake Ontario basin.

Effects on Lake Michigan

The results of the measurements made in this project are that 4800 kilograms of PCBs are coming into Lake Michigan in precipitation per year. To gage the significance of these inputs, the other known and estimated sources of PCBs are listed in Table 5. It can be seen that precipitation is now the major source of PCBs to Lake Michigan.

The industrial use of PCBs for such uses as heat transfer fluids, hydraulic fluids, in die casting operations, etc., has greatly decreased since 1971 when they ceased to be sold for those purposes. As there was little or no control over the use or discharge of PCBs prior to 1971, it is not known how much of these materials were discharged and reached Lake Michigan, or where these discharges occurred. An illustration of the possible magnitude of these sources to the Lake, is a manufacturer in Waukegan, Illinois, who used a commercial hydraulic fluid containing PCBs. The water effluents from this plant go mostly to Waukegan harbor, but some go to a ditch leading directly to the Lake. The manufacturer estimated that of the 3.8×10^6 kilograms of PCBs they purchased over a twenty year period, as much as 15% to 20% could have been discharged with their water effluents (Thomas 1976). Sediment samples taken in the harbor in 1976 show concentrations of PCBs as high as 4 mg/gm, and sediments from the ditch were as high as 0.6 mg/gm (IJC 1976b).

TABLE 5. INPUTS OF PCBs (KG/YR) TO LAKE MICHIGAN

Sources	Prior to 1975	1977
Major Industrial Discharges*	(25,000)	---
Precipitation#	4,800	4,800
Streams and Waste Water Effluents@	1,650	1,650
Others$	(2,500)	(2,500)
Total	33,950	8,950

*This estimate is a lower limit. The actual amount may be several times larger.

#This work.

@Hesse, J. L. (1976). Conference Proceedings. National Conference on Polychlorinated Biphenyls, Nov. 19-21, 1975, Chicago, IL., EPA 560/6-75/004; NTIS, PB-253 248/9PSX; p. 127.

@Kleinert, S. (1976). Conference Proceedings. National Conference on Polychlorinated Biphenyls, Nov. 19-21, 1975, Chicago, IL., EPA 560/6-75-004; NTIS, PB-253 248/9PSX; p. 124; Personal communication.

@Schacht, R. A. Pesticides in the Illinois Waters of Lake Michigan. EPA 660/3-74-002, January 1974.

$An estimate to attempt to account for dry deposition of PCBs on the Lake surface and to allow for small industrial discharges not yet identified.

To gage the significance of the precipitation inputs of PCBs to the Lake, the other known and estimated sources of PCBs to the Lake are listed in Table 5. These include the effluents from waste water treatment plants, those industries known to have PCBs in their discharges, and tributary inputs.

If Table 5 is reasonably accurate, and industrial discharges have greatly decreased, then when the Lake comes to equilibrium with the lower inputs, the concentration of PCBs in the water and biota should be much less than the present values. The data here indicate that the atmosphere will be the major contributor of PCBs and therefore, the levels of PCBs in the Lake and biota should reflect the magnitude of the inputs from this source.

The most recent information on the concentration of PCBs in Lake Michigan fish indicates that levels in chubs and coho salmon have declined by a statistically significant amount below the maximum values of recent years (Seelye 1977). Thus, it seems as if the concentration of PCBs in Lake biota are now beginning to respond to the decreased inputs of PCBs to the Lake.

The data in Table 3 and Figure 4 indicate that the different compartments associated with the Lake contain very different compositions of PCBs. For instance, the PCBs in air are 84 percent Aroclor^{R} 1242 while the Lake water is only 34 percent; and 66 percent of the PCBs in rain are filterable while only 33 percent of the PCBs in the Lake are. There are too few samples in most cases to give reliable information, and many of the compartments in the Lake are not represented, but it seems clear from these different compositions that, in the past, sources other than the air and precipitation have contributed PCBs to Lake Michigan.

DISTRIBUTION OF PCBs IN THE ATMOSPHERE BETWEEN VAPOR AND PARTICULATES

At the present, it has not possible to determine the extent to which PCBs are present as vapor and on particulates in the atmosphere. This is because PCBs on particulates, captured on the filter paper of high volume air particulate samplers, evaporate into the air stream and are collected as vapor. Thus, the total amount of PCBs present in the atmosphere can be readily determined, but their distribution between vapor and particulate forms can not be. The information obtained in this project, however, leads to a tentative resolution of this problem.

Where do the PCBs found in the precipitation come from? Either from PCBs present as vapor which dissolved in the precipitation, or as PCBs adsorbed on particulates which were scavenged by precipitation. The scavenging of PCB vapor by rain can be ruled out on theoretical and experimental grounds. On theoretical grounds, the distribution constant for the partition of PCBs between air and water, the Henry's Law Constant (HLC), is about 20 for Aroclor^{R} 1242 and 1254 (Junge 1977; Mackay and Leinonen 1975; Mackay and Wolkoff 1973). It should be similar for Aroclor 1260. Since the data in Table 2 indicate that the the concentration in precipitation is about 400 times that calculated using the mean concentration in air and the HLC, PCB vapor is not an important source of PCBs to precipitation. McClure (1976) has arrived at similar conclusions for DDT.

Experimentally, the scavenging of PCB vapor by the precipitation also can not explain the amounts of Aroclor 1260 found in the precipitation samples. From the summaries of the compositions of the air and precipitation samples in Table 2 and Figure 4, the air samples contain about 3 percent Aroclor^{R} 1260, while the precipitation samples contain more than 20 percent. The lower water solubility of the Aroclor^{R} 1260 compared to the other Aroclors^{R} studied here, would preclude the factor of six enhancement in the precipitation as compared to the air. The greater percentages of the Aroclor^{R} 1260 in the precipitation samples can only be explained by the air particulates being higher in Aroclor^{R} 1260, and the

PCBs in precipitation coming chiefly from the scavenging of these particulates. The greater proportions of the lower molecular weight Aroclors[R] found in the air samples must then be due to material present in the atmosphere as vapor.

Precipitation then is providing the solution to the sampling dilemma which exists for PCBs in the atmosphere. If all of the PCBs in the non-filterable fraction of the precipiation samples, and most, if not all, of the PCBs in the filtered portion are coming from air particulates, then precipitation is serving as a selective sampler for air particulates. And, while a rain droplet may have a different scavenging efficiency for different sized air particulates, this would make a difference only if the PCB composition of different sized particulates were different.

A comparison of the air and rain samples collected permits an approximate resolution of the PCBs present in the atmosphere into vapor and particulate forms. As mentioned before, the air samples show a mean Aroclor[R] 1260 concentration of about 3 percent, while the rain samples show a mean Aroclor[R] 1260 composition of 20 percent. Thus, a mass balance based on Aroclor[R] 1260 indicates that only about 15 percent of the PCBs in the atmosphere are on particulates. These results are in accord with the predictions of Junge (1977) that compounds with vapor pressures of about 10^{5} mm of Hg, should be present in the atmosphere chiefly as vapor, even in urban atmospheres.

The data in Table 4, page 17, support this conclusion. The values shown for the total PCB concentration in air particulates are clearly high by a factor of 2 to 4, if it is assumed that all of the PCBs found in the vapor and particulate phases were on the particulates. The simple explanation for this is that not all of the PCBs collected were on particulates, but rather were present in the atmosphere as vapor. The low value for the non-filterable PCBs/sample for the air samples, is due to the evaporation of the PCBs from the filter and their collection as filtered PCBs.

The evidence that much of the PCBs in the atmosphere in the Lake Michigan region are present as vapor has important ramifications for the validity of methods recently reported for the collection of the dry fallout of PCBs (Södergren 1973; McClure 1976) and DDT (Young et al. 1976). These methods all utilize collectors coated with a non-polar liquid to capture and hold particulate matter. But, since PCBs are quite soluble in non-polar liquids, the partition coefficient into the liquid would be such that the equilibrium concentration on PCBs would be in the milligrams per liter range. Thus, PCBs present in the atmosphere as vapor would be expected to be efficiently scavenged by the liquid coating. The deposition results reported from the use of these sampling techniques would include not only PCBs from dry deposition, but also from vapor scavenging. In fact, the scavenging of PCBs in the vapor state by non-polar liquids is so efficient that it is the basis for a method for the collection of PCB vapor (Harvey and Steinhauer 1974).

Further evidence that the PCBs in precipitation are coming from the scavenging of air particulates comes from measurements of the size of the

organic fraction and the scavenging efficiency one would expect for such particulates. Gatz (1977) has reported a correlation between scavenging ratios and the mass median diameter (MMD), of the particulates being scavenged. The smallest scavenging ratio he reported was 76 for lead, with a MMD of about 0.5 micrometers. Andren (1976) and Strand (1977) have reported that organic particulates in the atmosphere above Lake Michigan are less than 2 micrometers in MMD. The scavenging ratio of 25 found in this project is, when corrected for the fact that much of the PCBs are present as vapor, is in good agreement with the sizes found by Andren and Strand. Although other factors undoubtedly contribute to precipitation scavenging, the low scavenging ratio found for these samples indicate that the particulates being scavenged are quite small.

PCBs IN ORGANIC PARTICULATES

In order to be able to account for the distribution of PCBs in the environment and their movement through the environment, the concentration of the PCBs in the different compartments of the environment must be known. Due to their non-polar nature and large n-octanol/water partition coefficient, PCBs not in the vapor phase are always found associated with non-polar organic matter. Therefore, if the concentrations of PCBs in this organic matter, and the movement of the organic matter through the environment is known, the movement of the PCBs through the environment will also be known.

Data on the mean amount of hexane/acetone soluble (organic) and insoluble particulates present in the non-filterable fraction of the different types of samples collected in the project are in Table 4. Also shown are the results of calculations based on different assumptions on the source of the PCBs in the samples. Probably most of the PCBs in precipitation samples which are filterable are associated with small particulates. Thus the concentration of PCBs in organic material in the atmosphere may be best represented by the concentration of PCBs in the organic portion of the particulate fraction of the precipitaion samples.These results are all close to 100 mg/kg. The similarity of these values to those found for the concentrations of PCBs in the fat of fish from Lake Ontario (Heile et al. 1975), may be more than a coincidence.

PCBs IN GASES FROM LANDFILLS

PCBs in landfills have heretofore been considered only as a source of water pollution. While samples from one day, from a single landfill, allow no conclusions to be drawn, the high concentration of PCBs found in these samples (Table 2, p. 13) suggests that landfills may be a source of PCBs to the atmosphere and that further studies are in order.

PERCHLORINATION

The quantification of PCBs is complicated by the large number of separate chlorinated biphenyl compounds present in a sample and by the different sensitivity of the electron capture (EC) detector tot he different

compounds. It has been reported (Armour 1973) that, upon reaction with antimony pentachloride, PCBs are quantitatively perchlorinated to the fully chlorinated biphenyl, decachlorobiphenyl (DCB). Thus all of the different PCBs present are converted into one compound, and of all of the PCBs, the EC detector has the greatest sensitivity to DCB. It was hoped that the use of this reaction would greatly simplify the quantification of the PCBs.

While some initial control experiments using Aroclor^{R} 1254 were satisfactory, further experiments with Aroclor^{R} 1242 gave only about 25 percent conversion to the DCB. Careful attention to the evaporation of the samples raised this to 38 percent.

To check on the possibility that the perchlorination of the pure PCB standards was not different from the perchlorination of samples which contained large amounts of other organics, the following standard addition experiment was carried out. A portion of a precipitation sample was perchlorinated and the DCB produced was determined. A known amount of Aroclor^{R} 1242 was then added and the sample again perchlorinated. Only 40 percent of the theoretical amount of DCB was formed.

Since the yield of DCB was a function of the composition of the PCBs in the sample, and the percent of Aroclor^{R} 1242 in the different types of samples varied from 9 percent to 98 percent, it was decided that this method was not suitable for the quantification of the PCBs in the samples collected in this project.

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APPENDIX

Data from the different samples collected and analyzed in this project are included in the appendix. They include:

1. Rain samples collected in Chicago.

2. Rain samples collected on Beaver Island.

3. Lake Michigan water samples. The May, 1976 sample was collected in about 0.5 m of water at Beaver Island. The other samples were collected from a water intake crib of the city of Chicago in about 10 m of water. All of the samples were collected from beneath the surface.

4. Snow samples collected in Chicago.

5. Air samples. The Nov., 1975 sample was collected in Mammoth Cave National Park.

The percent composition of the Aroclors^{R} in the non-filterable portion of the samples shown in the appendix was calculated from a data base which included the measured percent composition for the filtered and total portions only. In those cases where the non-filterable portion of a particular Aroclor^{R} constitutes only a small portion of the total amount, there may be significant errors in the percentage shown in the appendix tables. The results in the report for the non-filterable portions of the samples were based on the measured values and thus should be free from these errors.

CHICAGO RAIN SAMPLES

SAMPLING DATE BEGUN YY MM DD	DURATION (HR)	RAIN (MM)	VOLUME COLLEC (L)	FILTERED % AROCLOR 1242	FILTERED % AROCLOR 1254	FILTERED % AROCLOR 1260	FILTERED TOTAL (NG)	NON-FILTERABLE % AROCLOR 1242	NON-FILTERABLE % AROCLOR 1254	NON-FILTERABLE % AROCLOR 1260	NON-FILTERABLE TOTAL (NG)	TOTAL SAMPLE % AROCLOR 1242	TOTAL SAMPLE % AROCLOR 1254	TOTAL SAMPLE % AROCLOR 1260	TOTAL SAMPLE TOTAL (NG)	PCB CONC (NG/L)	INPUT OF PCBS (NG/M2) (MG/KM2)
75 11 09	10.0	8.7	9.0	4.9	32.3	62.6	1030	0.0	0.0	0.0	0	4.9	32.3	62.6	1030	114.4	0.995
75 11 19	24.2	8.8	20.0	74.3	12.7	12.8	1542	0.0	0.0	0.0	0	74.3	12.7	12.8	1541	77.0	0.678
75 12 05	22.5	10.7	26.7	3.8	57.0	39.1	426	0.0	0.0	0.0	0	3.8	57.0	39.1	426	15.9	0.170
75 12 14	5.0	12.8	9.0	22.2	52.6	25.0	541	14.2	35.4	50.3	277	19.5	46.8	33.6	818	90.8	1.163
76 02 20	18.0	37.5	72.0	31.4	35.6	32.9	1122	0.0	0.0	0.0	0	31.4	35.6	32.9	1122	15.5	0.584
76 03 29	23.7	2.5	5.5	82.9	13.5	3.4	1194	11.3	72.6	16.2	381	65.6	27.8	6.5	1575	286.3	0.715
76 04 20	13.5	4.3	8.1	70.8	16.5	12.6	547	80.7	15.7	3.3	384	74.9	16.2	8.8	931	114.9	0.494
76 04 20	12.6	8.0	17.1	73.2	13.2	13.4	216	45.3	34.3	20.3	100	64.4	19.9	15.6	316	18.4	0.147
76 04 24	7.5	21.8	22.0	62.6	35.4	1.8	3243	0.2	##.#	1.8	80	61.1	37.0	1.8	3323	151.0	3.292
76 04 24	14.0	62.7	77.5	84.2	14.2	1.5	4944	22.2	74.4	2.3	661	76.9	21.3	1.6	5605	72.3	4.534
76 05 05	16.0	54.0	40.0	83.6	11.4	4.9	3393	20.1	54.3	24.9	1124	67.8	22.1	9.9	4517	112.9	6.097
76 05 13	18.5	3.4	3.2	75.8	21.3	2.8	460	68.6	27.3	3.8	1037	70.8	25.5	3.5	1498	468.1	1.591
76 05 15	0.5	4.6	2.7	78.7	19.8	1.3	641	37.4	59.8	2.5	213	68.4	29.8	1.6	854	316.2	1.454
76 07 20	19.0	23.5	23.7	70.2	18.2	11.5	1250	25.6	53.1	20.6	804	52.8	31.9	15.1	2053	86.6	2.035
76 07 22	17.0	12.8	8.3	74.1	19.0	6.7	1411	63.3	33.9	2.4	1055	69.5	25.4	4.9	2466	297.1	3.802
76 07 30	16.0	6.1	6.5	74.3	19.9	5.7	1574	27.4	64.2	8.2	863	57.7	35.6	6.6	2438	375.0	2.287
76 08 04	40.0	10.0	8.2	64.5	29.4	5.9	1419	14.2	79.2	5.8	920	44.8	49.1	5.9	2335	284.7	2.847
76 08 11	16.0	5.5	5.7	10.5	38.8	50.5	503	10.1	54.0	35.6	912	10.3	48.6	40.9	1415	248.2	1.365
76 09 08	0.0	14.0	16.3	54.7	41.2	4.0	292	18.2	75.2	6.2	896	27.2	66.9	5.7	1188	72.8	1.020
76 09 25	15.5	28.6	34.3	27.9	61.9	10.0	630	19.5	63.2	17.0	268	25.4	62.3	12.1	898	26.1	0.748
76 10 23	4.7	12.7	15.2	15.2	50.1	34.6	630	12.0	63.3	24.3	1293	13.1	59.0	27.7	1923	126.5	1.606
76 10 04	39.0	33.5	36.7	46.1	5.5	48.3	605	20.6	58.4	20.6	855	31.2	36.5	32.1	1460	39.7	1.332

BEAVER ISLAND RAIN SAMPLES

SAMPLING DATE BEGUN YY MM DD	DURATION (HR)	RAIN (MM)	VOLUME COLLEC (L.)	FILTERED % AROCLOR 1242	1254	1260	TOTAL (NG)	NON-FILTERABLE % AROCLOR 1242	1254	1260	TOTAL. (NG)	TOTAL SAMPLE % AROCLOR 1242	1254	1260	TOTAL (NG)	PCB CONC (NG/L.)	INPUT OF PCBS (NG/M2) (NG/KM2)
76 05 09	5.7	12.2	15.8	37.4	52.7	9.8	392	26.2	55.7	17.7	1401	28.7	55.1	16.0	1793	113.4	1.384
76 06 13	9.5	5.0	6.1	42.0	46.1	11.6	879	32.0	60.2	7.4	504	38.4	51.3	10.1	1382	226.5	1.132
76 06 15	3.7	2.3	2.1	19.2	69.9	10.8	285	5.8	68.4	25.9	174	14.1	69.2	16.5	460	219.0	0.503
76 06 18	2.3	5.6	6.5	20.7	43.3	35.9	711	37.5	42.7	19.5	160	23.8	43.2	32.9	871	134.0	0.750
76 06 24	13.0	0.9	1.3	43.3	40.0	16.5	342	24.4	43.4	31.9	289	34.7	41.6	23.6	631	485.3	0.436
76 07 29	0.0.	5.8	7.2	51.3	33.4	15.2	1429	25.1	57.6	17.1	816	41.8	42.2	15.9	2245	311.8	1.808
76 08 00	0.2	14.7	7.5	19.6	46.3	33.9	337	52.2	47.6	0.1	279	34.4	46.9	18.6	616	82.1	1.207
76 08 27	0.0	12.2	4.8	40.0	55.3	4.6	670	18.4	51.7	29.6	700	29.0	53.5	17.4	1370	285.4	3.482
76 08 31	16.0	13.2	16.5	24.1	73.5	2.3	570	26.2	58.1	15.7	521	25.1	66.1	8.7	1092	66.1	0.873
76 09 14	7.0	4.5	5.2	58.0	32.6	9.2	220	9.6	50.0	40.7	151	38.2	39.6	22.0	372	71.5	0.321
76 09 29	5.0	5.2	6.5	22.5	56.5	20.8	396	35.9	31.8	31.8	577	30.5	41.9	27.4	972	149.5	0.777
76 10 04	13.0	26.7	28.3	37.0	34.1	28.8	1034	29.6	37.7	32.2	563	34.4	35.4	30.0	1597	56.4	1.506
76 10 14	3.0	1.8	2.1	29.8	44.5	25.6	506	39.9	27.9	31.9	757	35.9	34.6	29.4	1263	601.4	1.082

LAKE MICHIGAN WATER SAMPLES

SAMPLING DATE BEGUN YY MM DD	DURATION (HR)	VOLUME COLLEC (L)	FILTERED % AROCLOR 1242	1254	1260	TOTAL (NG)	NON-FILTERABLE % AROCLOR 1242	1254	1260	TOTAL (NG)	TOTAL SAMPLE % AROCLOR 1242	1254	1260	TOTAL (NG)	PCB CONC (NG/L)
76 05 22	0.0	14.7	19.8	68.6	11.5	191	66.4	27.6	5.8	249	46.2	45.4	8.3	440	29.9
76 09 22	0.0	15.5	14.4	76.4	9.1	195	24.1	71.4	4.2	473	21.3	72.9	5.7	668	43.0
76 09 22	0.0	13.5	14.3	75.7	9.9	160	49.4	48.1	2.1	362	38.7	56.6	4.5	522	38.6

CHICAGO SNOW SAMPLES

SAMPLING DATE BEGUN YY MM DD	DURATION (HR)	VOLUME COLLEC (L)	FILTERED % AROCLOR 1242	1254	1260	TOTAL (NG)	NON-FILTERABLE % AROCLOR 1242	1254	1260	TOTAL (NG)	TOTAL SAMPLE % AROCLOR 1242	1254	1260	TOTAL (NG)	PCB CONC (NG/L)
75 12 29	25.0	12.7	83.7	9.5	6.6	546	4.4	55.6	39.7	226	60.5	23.0	16.3	772	60.7
76 01 21	3.0	10.5	57.0	36.0	6.9	766	29.4	58.9	11.5	1414	39.1	50.9	9.9	2180	207.6
76 12 06	17.0	6.0	33.3	35.2	31.3	764	25.2	55.3	19.2	764	29.3	45.3	25.3	1527	254.5
77 01 10	0.0	8.7	47.5	40.7	11.6	576	21.9	57.4	20.3	2271	27.1	54.1	18.6	2847	327.2

AIR SAMPLES

SAMPLING DATE BEGUN YY MM DD	DURATION (HR)	VOLUME COLLEC (M3)	FILTERED % AROCLOR 1242	FILTERED % AROCLOR 1254	FILTERED % AROCLOR 1260	FILTERED TOTAL (NG)	NON-FILTERABLE % AROCLOR 1242	NON-FILTERABLE % AROCLOR 1254	NON-FILTERABLE % AROCLOR 1260	NON-FILTERABLE TOTAL (NG)	TOTAL SAMPLE % AROCLOR 1242	TOTAL SAMPLE % AROCLOR 1254	TOTAL SAMPLE % AROCLOR 1260	TOTAL SAMPLE TOTAL (NG)	PCB CONC (NG/M3)
75 11 27	32.0	1788	80.3	19.1	0.5	11469	45.2	54.2	2.6	547	78.7	20.7	0.6	12017	6.7
75 12 05	20.7	1106	93.2	6.2	0.6	7517	0.7	12.6	85.5	771	84.6	6.8	8.5	8288	7.4
76 02 20	21.4	1072	86.4	10.2	3.4	3646	14.3	36.6	46.0	266	81.5	12.0	6.3	3912	3.6
76 03 29	20.0	1138	75.3	24.4	0.2	11275	75.3	42.6	0.2	62	75.3	24.5	0.2	11337	9.9
76 04 19	28.9	954	94.7	4.7	0.5	10385	28.4	48.8	15.2	143	93.8	5.3	0.7	10528	11.0